

CLAIMS

We claim:

1. A method for making a positive active material, comprising the acts of:
exposing olivine or nasicon to a carbon source gas; and then
heating the carbon source gas to generate carbon material and deposit the carbon material
on the olivine or nasicon.
2. The method of claim 1 wherein said olivine or nasicon comprises nasicon,
 $A_nB_2(XO_4)_3$, wherein
A is chosen from the group consisting of: Li, Ag, Cu, Na, Mn, Fe, Co, Ni, Cu, and Zn;
B is chosen from the group consisting of: Ti, V, Cr, Fe, and Zr;
X is chosen from the group consisting of: P, S, Si, W, Mo; and
n is between 0 and 3.
3. The method of claim 1 wherein said olivine or nasicon comprises olivine,
 $LiFe_{1-x}M_xPO_4$, wherein
M is chosen from the group consisting of Mn, Co, Ti, and Ni; and
 $0 \leq x \leq 1$.
4. The method of claim 1 wherein said carbon source gas is heated to between 100°C
and 1300°C to generate carbon material.
5. The method of claim 1 wherein said carbon source gas is heated to between 400°C
and 700°C to generate carbon material.
6. The method of claim 1 wherein said carbon source gas is chosen from the group
consisting of: acetylene, butane, 1-3 butadiene, 1-butene, Cis-2-butene, Trans-2-butene, 2-2
dimethylpropane, ethane, ethylene, isobutane, isobutylene, methane, propane, toluene,
propylene, and mixtures thereof.
7. The method of claim 1 wherein said heating step occurs in a furnace chosen from the
group consisting of: a fluidized bed furnace, a rotatory furnace, and a static furnace.
8. The method of claim 1 wherein said carbon source gas is mixed with an inert gas.

9. The method of claim 8 wherein said inert gas is chosen from the group consisting of: nitrogen, helium, argon, and mixtures thereof.

10. Positive active material made by the process of:
exposing olivine or nasicon to a carbon source gas; and
heating the carbon source gas to deposit carbon onto said olivine or nasicon.

11. The positive active material of claim 10 wherein said olivine or nasicon comprises olivine.

12. The positive active material of claim 10 wherein said olivine or nasicon comprises nasicon.

13. The positive active material of claim 10 wherein said olivine or nasicon contains pores and wherein said carbon is deposited within said pores.

14. The positive active material of claim 10 wherein the amount of deposited carbon is <15 wt%.

15. The positive active material of claim 10 wherein the amount of deposited carbon is about 4 wt% or less.

16. The positive active material of claim 10 wherein said carbon source gas decomposes at a temperature between 100°C and 1300°C to generate carbon.

17. The positive active material of claim 16 wherein said carbon source gas decomposes at a temperature between 400°C and 700°C to generate carbon.

18. The positive active material of claim 10 wherein said carbon source gas is chosen from the group consisting of: acetylene, butane, 1-3 butadiene, 1- butene, Cis-2- butene, Trans-2- butene, 2-2 dimethylpropane, ethane, ethylene, isobutane, isobutylene, methane, propane, toluene, propylene, and mixtures thereof.

19. The positive active material of claim 10 wherein said heating step occurs in a furnace chosen from the group consisting of: a fluidized bed furnace, a rotatory furnace, and a static furnace.

20. The positive active material of claim 10 wherein said carbon source gas is mixed with an inert gas.

21. The positive active material of claim 20 wherein said inert gas is chosen from the group consisting of: nitrogen, helium, argon, and mixtures thereof.

22. A positive electrode comprising:

a current collector; and

a coating on said current collector, said coating comprising a mix of the positive active material of claim 10 and a binder.

23. The electrode of claim 22 wherein said coating further comprises a conductive additive.

24. The electrode of claim 22 wherein said current collector is aluminum having a carbon coating thereon.

25. The electrode of claim 24 wherein the thickness of said carbon coating on said aluminum is less than 80 microns.

26. The electrode of claim 24 wherein the thickness of said carbon coating on said aluminum is less than 30 microns.

27. The electrode of claim 24 wherein the thickness of said carbon coating on said aluminum is less than 15 microns.

28. The electrode of claim 24 wherein the thickness of said carbon coating on said aluminum is less than 10 microns.

29. The electrode of claim 24 wherein the thickness of said carbon coating on said aluminum is about 3 microns or less.

30. The electrode of claim **24** wherein the thickness of said carbon coating on said aluminum is less than 2 microns.

31. A battery comprising:

a positive electrode comprising the positive active material of claim **10**;

a negative electrode; and

an electrolyte.

32. The battery of claim **31** wherein the amount of carbon deposited on said olivine or nasicon is <15 wt%.

33. The battery of claim **31** wherein the amount of carbon deposited on said olivine or nasicon is about 4 wt% or less.

34. The battery of claim **31** wherein said carbon source gas is a gas that decomposes at a predetermined temperature to generate carbon.

35. The battery of claim **34** wherein said temperature is between 100°C and 1300°C.

36. The battery of claim **31** wherein said carbon source gas is chosen from the group consisting of: acetylene, butane, 1-3 butadiene, 1- butene, Cis-2- butene, Trans-2- butene, 2-2 dimethylpropane, ethane, ethylene, isobutane, isobutylene, methane, propane, toluene, propylene, and mixtures thereof.

37. The battery of claim **31** wherein said carbon source gas is mixed with an inert gas.

38. The battery of claim **37** wherein said inert gas is chosen from the group consisting of: nitrogen, helium, argon, and mixtures thereof.

39. The battery of claim **31** wherein said electrolyte is a nonaqueous electrolyte.

40. The battery of claim **31** wherein said electrolyte comprises a salt dissolved in a solvent comprising at least one linear or cyclic carbonate.

41. The battery of claim **40** wherein said salt is chosen from the group consisting of: LiClO_4 , LiPF_6 , LiBF_4 , LiAsF_6 , LiCF_3SO_3 , $\text{Li}(\text{CF}_3\text{SO}_2)_2\text{N}$, $\text{Li}(\text{CF}_3\text{SO}_2)_3\text{C}$, $\text{LiN}(\text{SO}_2\text{C}_2\text{F}_5)_2$, Li-methide, Li-imide, lithium alkyl fluorophosphate, lithium bis(chelato)borate, and a mixture thereof.

42. The battery of claim **31** wherein said negative electrode comprises a material chosen from the group consisting of: lithium metal, graphite, other carbon, Cu_6Sn_5 , Cu_2Sb , MnSb , other metal alloys, $\text{Li}_4\text{Ti}_5\text{O}_{12}$, silica alloys, and mixtures thereof.

43. A positive electrode comprising:

a current collector comprising aluminum having a carbon coating thereon; and
a positive active material comprising olivine or nasicon on said current collector.

44. The positive electrode of claim **43** wherein the thickness of said carbon coating on aluminum current collector is less than 80 microns.

45. The positive electrode of claim **43** wherein the thickness of said carbon coating on aluminum current collector is less than 30 microns.

46. The positive electrode of claim **43** wherein the thickness of said carbon coating on aluminum current collector is less than 15 microns.

47. The positive electrode of claim **43** wherein the thickness of said carbon coating on aluminum current collector is less than 10 microns.

48. The positive electrode of claim **43** wherein the thickness of said carbon coating on aluminum current collector is about 3 microns or less.

49. The positive electrode of claim **43** wherein the thickness of said carbon coating on aluminum current collector is less than 2 microns.

50. The positive electrode of claim **43** wherein said positive active material is made by the process of:

exposing olivine or nasicon to a carbon source gas; and
heating the carbon source gas to deposit carbon onto said olivine or nasicon..

51. The positive electrode of claim **50** wherein the amount of carbon deposited on said olivine or nasicon is <15 wt%.

52. The positive electrode of claim **50** wherein the amount of carbon deposited on said olivine or nasicon is about 4 wt% or less.

53. A battery comprising:

a positive electrode comprising the positive active material of claim **41**;
a negative electrode; and
an electrolyte.

54. The battery of claim **53** wherein the amount of carbon deposited on said olivine or nasicon is <15 wt%.

55. The battery of claim **53** wherein the amount of carbon deposited on said olivine or nasicon is about 4 wt% or less.

56. The battery of claim **53** wherein said carbon source gas is a gas that decomposes at a predetermined temperature to generate carbon.

57. The battery of claim **56** wherein said temperature is between 100°C and 1300°C.

58. The battery of claim **53** wherein said carbon source gas is chosen from the group consisting of: acetylene, butane, 1-3 butadiene, 1- butene, Cis-2- butene, Trans-2- butene, 2-2 dimethylpropane, ethane, ethylene, isobutane, isobutylene, methane, propane, toluene, propylene, and mixtures thereof.

59. The battery of claim **53** wherein said carbon source gas is mixed with an inert gas.

60. The battery of claim **59** wherein said inert gas is chosen from the group consisting of: nitrogen, helium, argon, and mixtures thereof.

61. The battery of claim **53** wherein said electrolyte is a nonaqueous electrolyte.

62. The battery of claim **53** wherein said electrolyte comprises a salt dissolved in a solvent comprising at least one linear or cyclic carbonate.

63. The battery of claim **62** wherein said salt is chosen from the group consisting of: LiClO_4 , LiPF_6 , LiBF_4 , LiAsF_6 , LiCF_3SO_3 , $\text{Li}(\text{CF}_3\text{SO}_2)_2\text{N}$, $\text{Li}(\text{CF}_3\text{SO}_2)_3\text{C}$, $\text{LiN}(\text{SO}_2\text{C}_2\text{F}_5)_2$, Li-methide, Li-imide, lithium alkyl fluorophosphate, lithium bis(chelato)borates, and mixtures thereof.

64. The battery of claim **53** wherein said negative electrode comprises a material chosen from the group consisting of: lithium metal, graphite, other carbon, Cu_6Sn_5 , Cu_2Sb , MnSb , other metal alloys, $\text{Li}_4\text{Ti}_5\text{O}_{12}$, silica alloys, and mixtures thereof.